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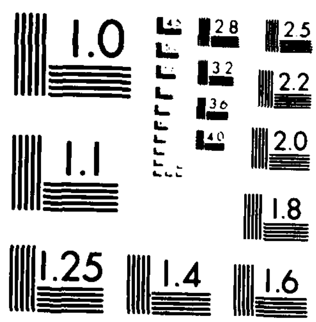

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OPTICAL, RADIO AND COMPUTER SIMULATION STUDIES OF THE BRAZIL IONOSPHERIC MODIFICATION EXPERIMENT OF 8 SEPTEMBER 1982

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Brazil Ionospheric Modification Experiments (BIME) provided an opportunity to conduct simultaneous airglow and electron content observations during a space plasma "active experiments" campaign in Natal, Brazil, in September 1982. A period of background data was also obtained, and computer simulation studies were conducted for the background and artificially disturbed conditions. The BIME - 1 release produced a depletion in TEC of 1-1.5 TEC units that was accompanied by an airglow burst of approximately

500 R at 6300 A. Wide-angle imaging at 6300 Å revealed an airglow cloud that extended to 150 km in radius. Post mission simulation studies carried out using the Boston University Finite Element Simulation (FES) Code were in good agreement with the observations.

1. OBSERVATIONS

The Boston University observing site at Jundiai (5.88^{o}S, 35.3^{o}W) was chosen using a nominal rocket trajectory and an average position for SIRIO of 0^{o}, 15^{o}W. With a release placed at 320 km, a ray path from Jundiai to the average position of SIRIO would have passed within 5 km of the center of the release. Using post flight trajectory data and an updated position for SIRIO, the actual miss distance for BIME-1 was $\sim$40 km. This was mostly due to an error in the original position for SIRIO. Figure 1 illustrates the viewing geometry for Jundiai.

The instrumentation at Jundiai included: 1) a VHF Polarimeter, 2) a 1^{o} field of view photon counting system using 7774, 6300, 6200, and 5577 Å filters, 3) two all-sky intensified cameras operating at the same wavelengths as the photon counter.

The BIME-1 release occurred on 8 September at 21:45:20 UT (19:23 LMT). A 40 minute section of the Polarimeter record is shown in Figure 2. The top trace is the amplitude record and the bottom trace records Faraday rotation angle. The release is not evident on the amplitude record; however, it can be seen on the phase record as a change in slope of the normal decay in TEC. The release caused a 1 to 1.5 TEC unit drop to occur in about 5 minutes with some evidence for recovery at later times.

Figure 3 shows the recorded 6300 Å airglow intensity (uncorrected for atmosphere transmission) obtained with the photon counter that was coaligned with the ray path to SIRIO. The pre-event level of $\sim$40 Rayleighs was enhanced by a factor of about 15 to $\sim$550 R.

The peak brightness occurred 3 minutes after the release and decayed to the pre-event background in about 20 minutes. The 6200 Å channel recorded no change from pre-event levels as did the 7774 Å channel. There is some weak evidence for a $\sim$50 R enhancement in 5577. The background at 5577 may have been as high as

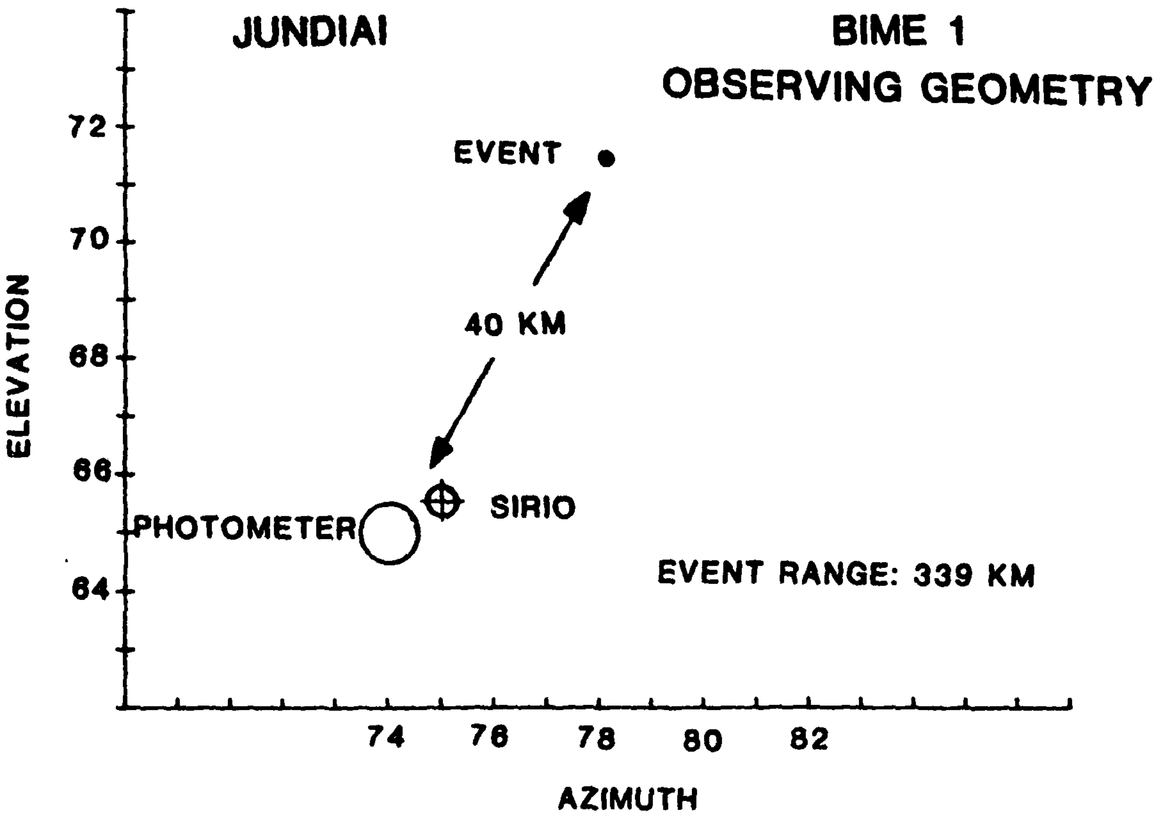


Figure 1. Observing Geometry

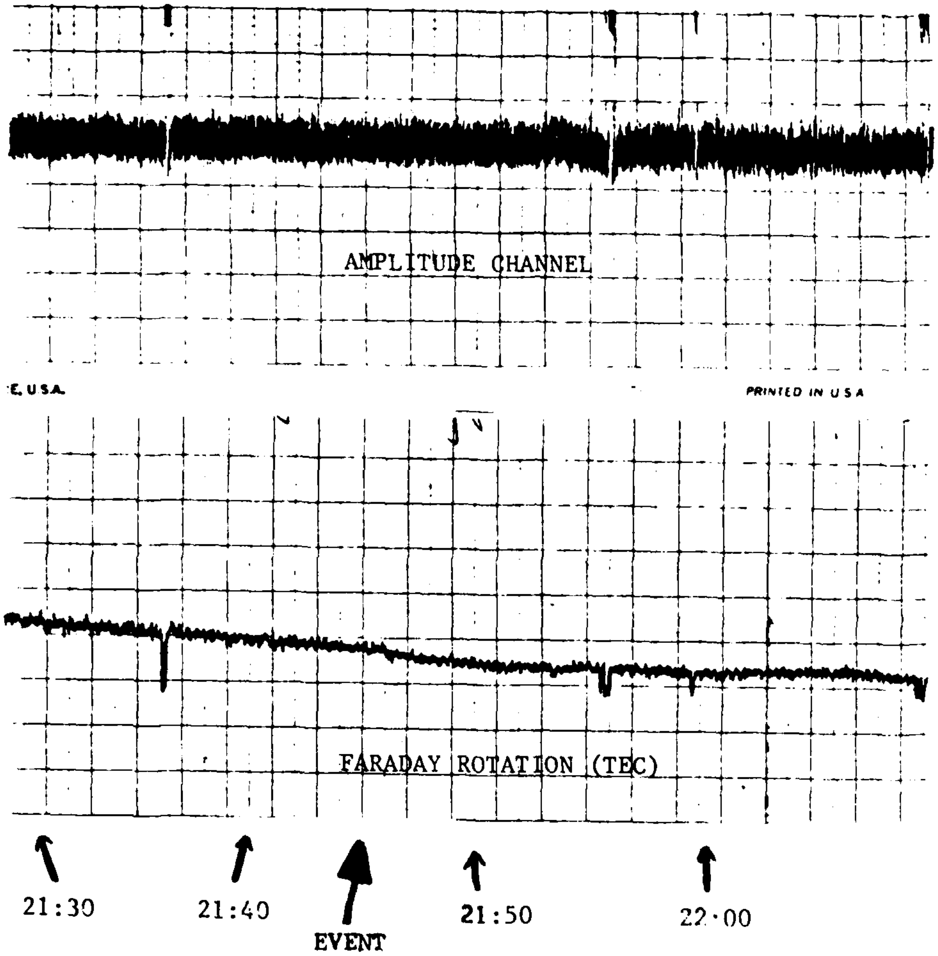


Figure 2. TEC and Amplitude Observations Using the SIRIO - Jundiai Ray Path During BIME-1, 8 September 1982.

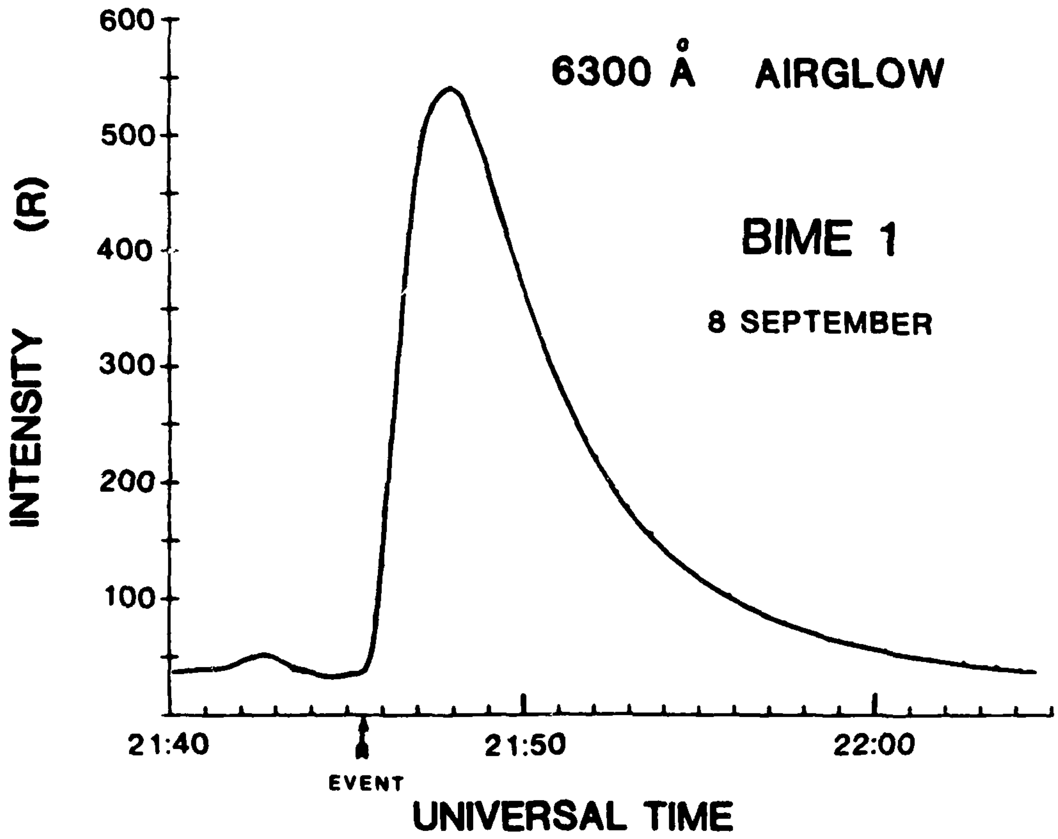


Figure 3. 6300A Photometer Curve

$\sim$400 R masking this increase.

The intensified cameras were operated in 60° field of view modes for the first 4 minutes after the release. System 1 had 6300 Å and 6200 Å filters. System II used a 5577 filter for the first 4 minutes, then started sequencing through 6300, 6200, 5577 and 7774 Å. No effect was seen in this camera other than at 6300 Å. After $\sim$4 minutes the airglow cloud was observed to be filling the 60° field of view of the cameras and the lenses were switched to 180° field of view. Two examples of 6300 Å photographs are shown in Figures 4 and 5 (Figure 5 also shows the Sonda Rocket). The brightness of the photographed cloud is consistent with the photometer measurements; the photographs show the cloud to be $\sim$150 km in radius. Photographs taken about 1 hour after the release show weak evidence for a field aligned depletion in the 6300 Å background to the east of the release point.

The background ionosphere at Natal during the September 1982 BIME/Colored Bubbles campaign proved to be more stable than we had hoped, with episodes of natural spread F and scintillations increasing as the month progressed. On September 12, a well defined period of scintillation occurred with corresponding bite-outs in the TEC record.

Also on this night airglow structure was seen by the photometer as well as the more sensitive of the two all-sky cameras. Figure 6 shows the diurnal TEC curve for this night (the average behavior of TEC during the campaign is marked by X's). The two bite-outs in TEC are seen around 21:30 and 22:30. Figure 7 is an expanded view showing the 2 hours around the time when the depletions were passing through the polarimeter and photometer beams. Notice that the 7774 Å record very closely tracks the TEC record while the two 6300 Å channels appear to have little or no correlation to the TEC record.

All sky photographs were taken during this period and are shown in Figures 8, 9 and 10. Figure 8 is a photograph at 7774 that clearly shows 2 depletions--

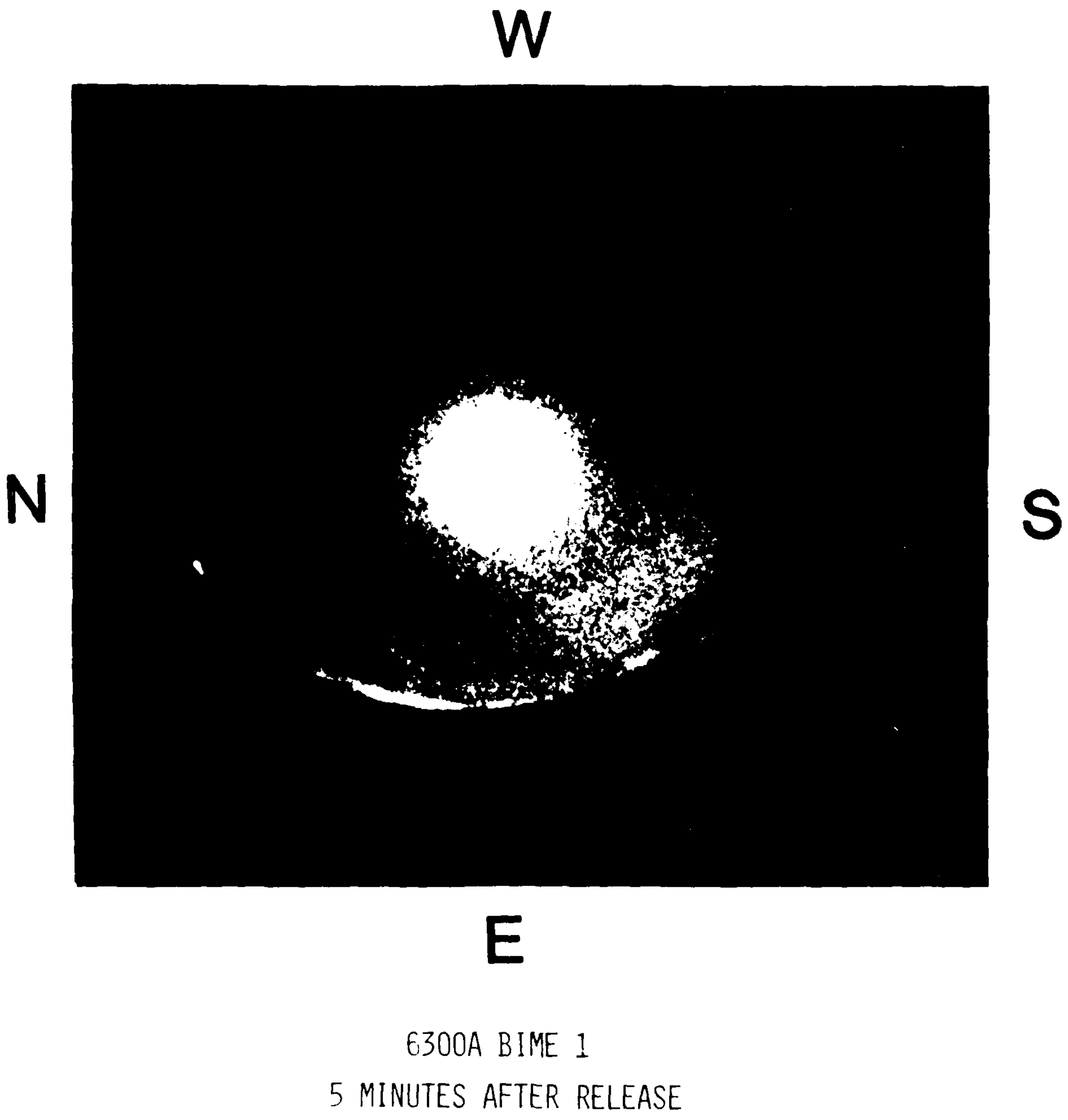
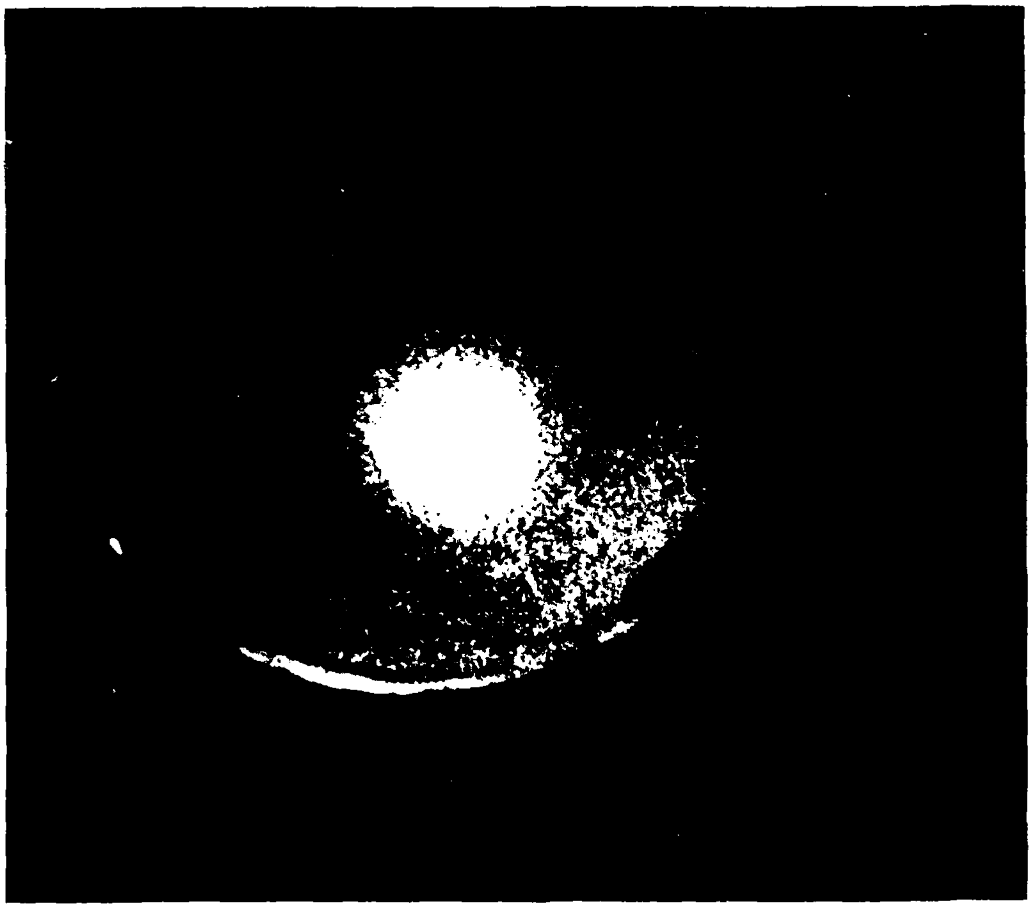


Figure 4, All Sky Image At T=5min (from 35mm slide)



6300A BIME 1

7 MINUTES AFTER RELEASE

Figure 5. All Sky Image Showing SONDA (from a 35mm slide)

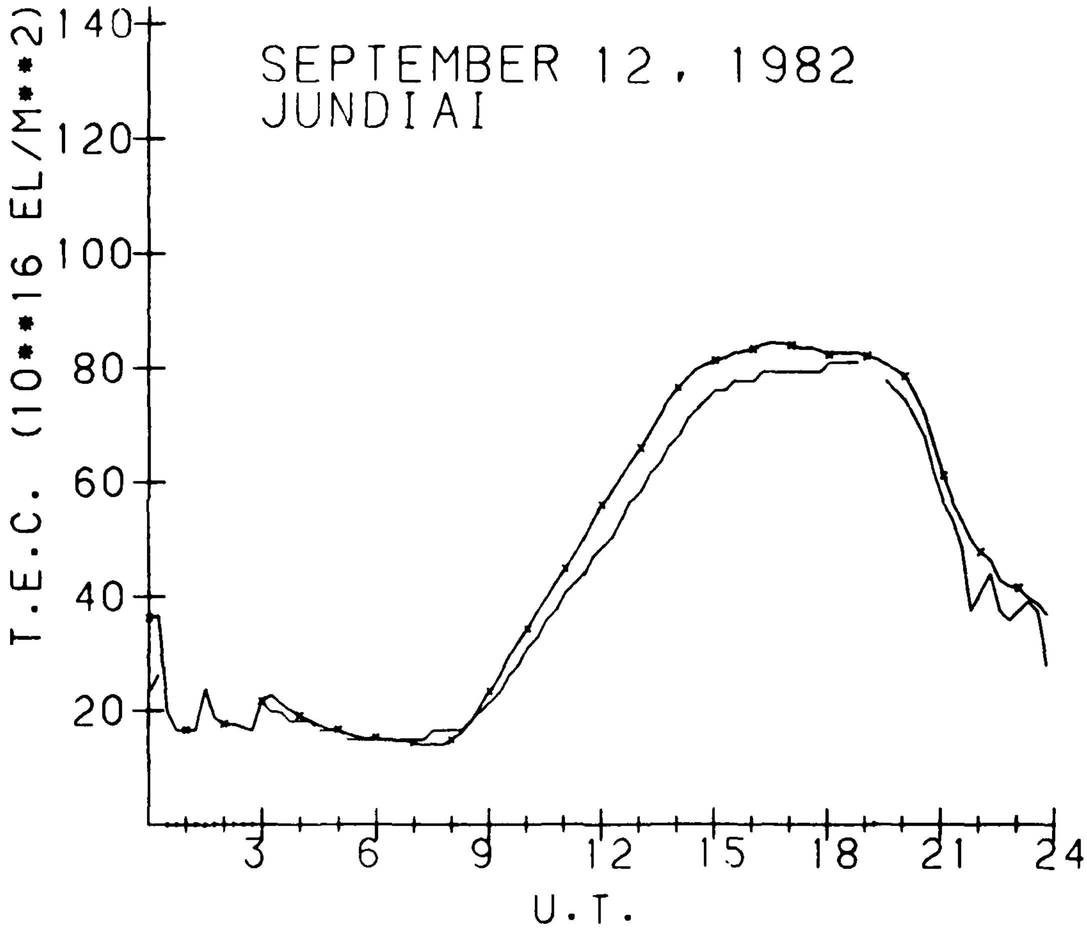


Figure 6, TEC Curve for September 12

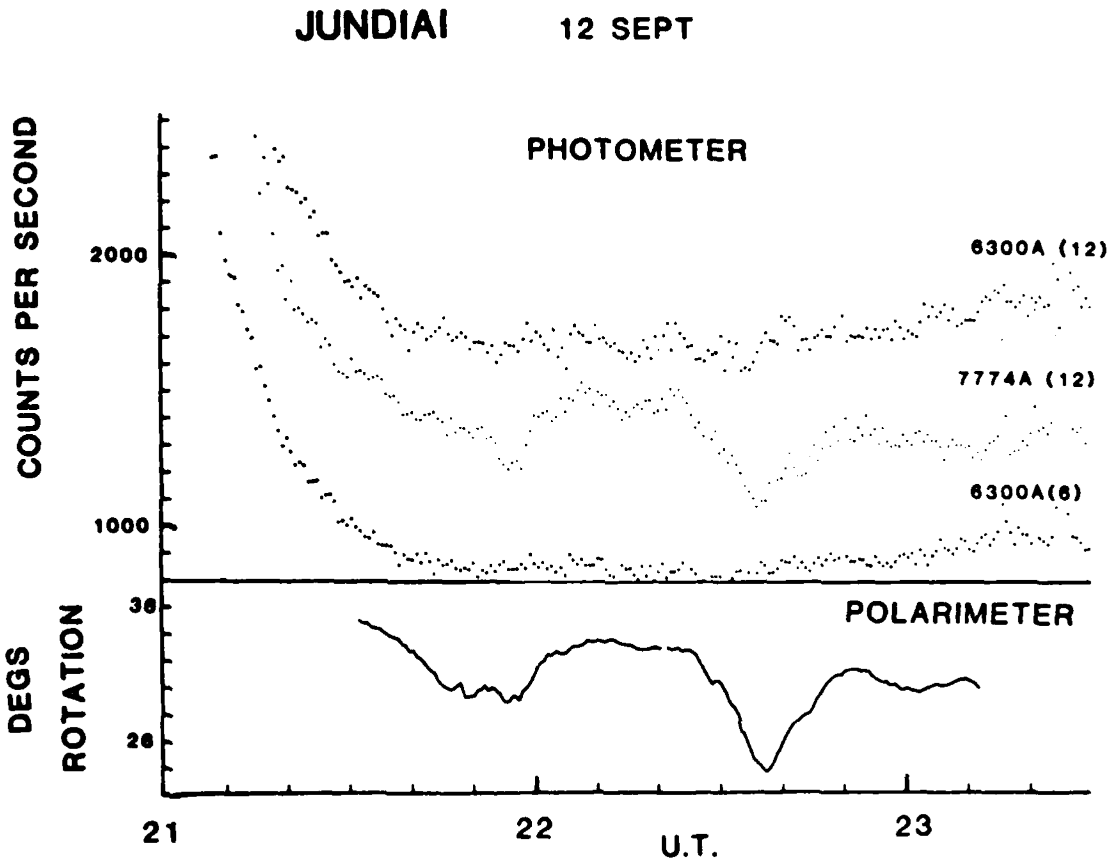


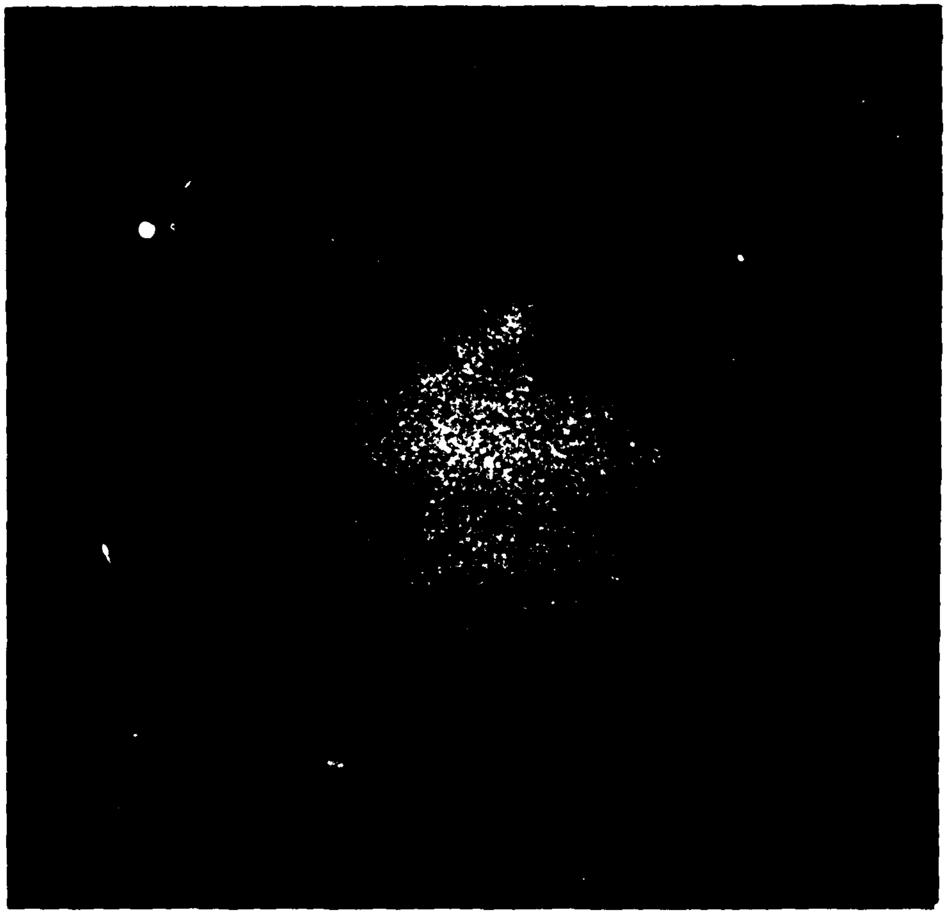
Figure 7. 6300 A, 7774 A and 6300 A (narrow filter) photometer data in comparison to TEC data for a period on 12 September 1982.

7774A SEPTEMBER 12
21:54 U.T.

Figure 8. All Sky Image With 7774 Depletions(from a 35mm slide)

6300A SEPTEMBER 12
21:55 U.T.

Figure 9. All Sky Image With 6300 Structures(from a 35mm slide)



7774A SEPTEMBER 12

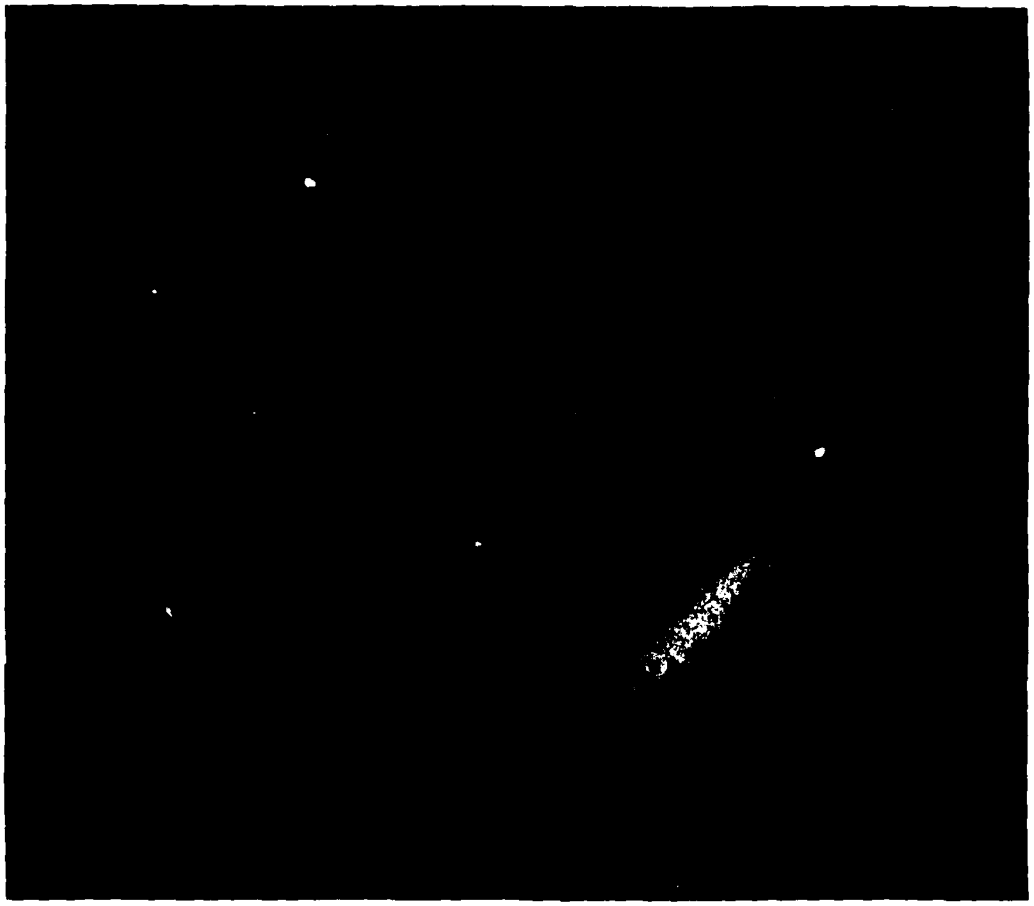
22:29 U.T.

Figure 10, All Sky Image With 7774 Depletions(from a 35mm slide)

6300A SEPTEMBER 14

22:40 U.T.

Figure 11. All Sky Image With 6300 Depletions [illegible]



6300A SEPTEMBER 18

01:07 U.T.

Figure 12. All Sky Image With 6300 Depletions(from a 35mm slide)

the one nearest the center of the field of view is the one that causes the bite-out in TEC at ∿21:50. The depletions near the edge of the field of view must have formed to the east of the ray path to SIRIO and drifted farther to the east, as its signature does not appear on the polarimeter records.

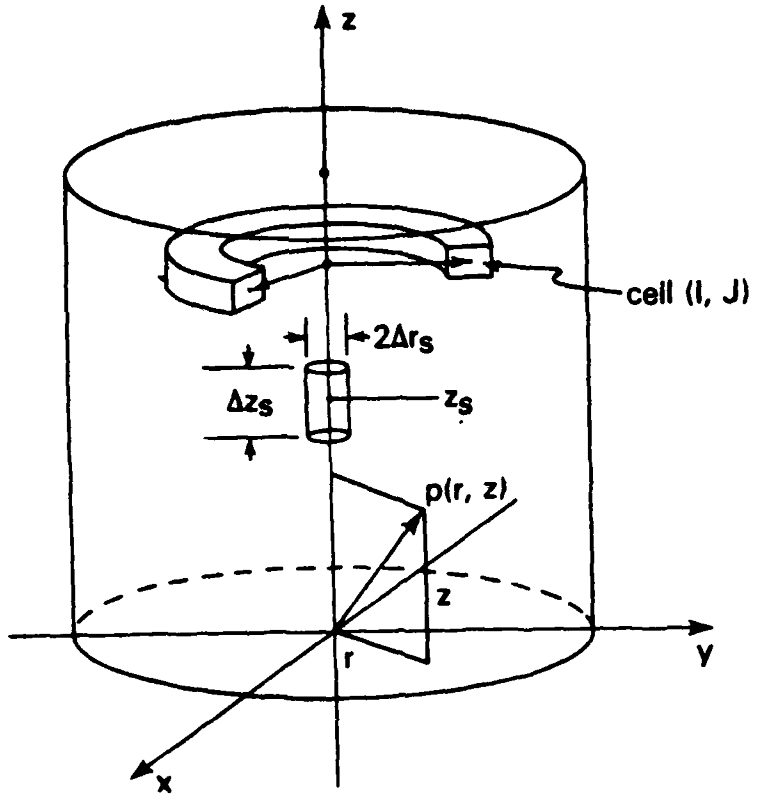
Figure 9 is a 6300 Å photograph taken just 1 minute after the 7774 exposure. Rather than a depletion there appears to be a ridge of 6300 airglow between the two 7774 depletions. Figure 10 is another 7774 exposure taken about 40 minutes after Figure 8 (this is about the time that the second bite-out occurred in the TEC record). Other instances of optical depletions in 6300 Å are shown in Figures 11 and 12. Out of the 13 nights that optical data were taken at Jundiai 5 nights showed evidence of depletions.

II. MODEL RESULTS

The geometry of the Boston University Finite Element Simulation (FES) Code is shown in Figure 13. The model uses cylindrical symmetry with 20 height bins and 10 radius bins. The allowed chemistry (reactants and products) for the BIME series of releases is shown on the lower left-hand side of Figure 13, while species that are allowed to diffuse are shown on the right. A complete description of the model is given elsewhere (Vance and Mendillo, 1981). The initial conditions for the BIME-1 simulation are outlined in Figure 14. The geomagnetic index Ap=100 was used for the input to the MSIS neutral atmosphere model which is the three-day average for 6-7-8 September. We feel that this high Ap index value was warranted due to the major magnetic storm that preceded the BIME-1 experiment. The baseline electron density profile used as input to the model was a composite profile from in-situ rocket, ionosonde and TEC data. The amount of released material available for chemistry in the simulation was 22 kg of H_2O and 19 kg of CO_2. This represents 40% of the H_2O released and 100% of the CO_2. This is probably a lower limit of the amount of H_2O available for chemistry -- the actual amount

Boston University

FINITE ELEMENT SIMULATION CODE



Chemistry		Transport	
O_2	O^+	H_2O	O^+
N_2	O_2^+	CO_2	O_2^+
CO_2	NO^+	$O(^1D)$	NO^+
H_2O	H_2O^+		H_2O^+
	E^-		E^-
	$O(^1D)$		

Figure 13. Simulation Geometry

INITIAL CONDITIONS

- MSIS NEUTRAL ATMOSPHERE: EVALUATED FOR BIME 1 CONDITIONS
  AP=100
- NE(H) PROFILE: OBSERVED BOTTOM SIDE PROFILE (BUCHAU)
  TOPSIDE DERIVED TO FIT TEC (KLOBUCHAR)
- RELEASE: 60% H_2O FROZEN, ALL CO_2 AVAILABLE (BEST FIT TO
  LAGOPEDO RESULTS)
- REACTION RATES: ALL FROM RECENT REVIEW ARTICLES
- AIRGLOW PRODUCTION: $O_2^+ + e^- \rightarrow \kappa O^* + (2-\kappa)\, O$
  (6300A FROM CO_2 CHAIN) $\kappa=1.0$ (REF. $0.9 \leq \kappa \leq 1.33$)
  (NO 6300A FROM H_2O CHAIN)
  QUENCHING OF O^* FROM N_2, O_2, CO_2, H_2O, e^-

Figure 14. Initial Conditions

may be as much as twice this value. The effect of increasing the amount of H_2O available for chemistry would be to increase the size and depth of the TEC "hole" but have little or no effect on the airglow since all of the modification-induced 6300 Å airglow in the model comes from reactions initiated by the CO_2.

The results of a 10 minute simulation of the BIME-1 release are summarized in Figures 15 through 24. It can be seen from Figures 15 and 16 that the release steepened the bottom side gradient and that the effect of the release did not extend much above 360 km. In characterizing the maximum effect of the release on electron densities, two plots were prepared: Figure 17 shows the electron density as a function of radius from the release point at the release height of 320 km. Figure 18 shows the same data but in terms of percent change from baseline conditions. From the second figure it can be seen that the maximum effect was a $\sim$70% depletion in electron density at the release point and the radius at which there was only a 1% effect was $\sim$100 km.

The effect of the release on the TEC is shown in Figures 19 and 20. The maximum change in TEC from Figure 19 is $\sim$1.5 TEC units. Figure 20 shows that at 80 km radius the effect on TEC is about 1%--similar to the size of the "hole" in electron density at the release height.

The effect of the release on 6300 Å airglow is summarized in the remaining figures. The baseline volume emission profile (O^1D concentration) and the effect of the release is shown in Figure 21. Figure 22 shows the time history of 6300 Å airglow at different radii from the release point. It can be seen that the model predicts a fairly strong gradient in brightness at early times--a factor of four within 60 km of the cloud center. This is somewhat steeper than was observed by the all-sky cameras. The size with the airglow cloud predicted by the release is shown in Figures 23 and 24. Figure 24 shows that the radius at which the percent change in airglow is $\sim$1% is an excess of 150 km, and that at 80 km where the per-

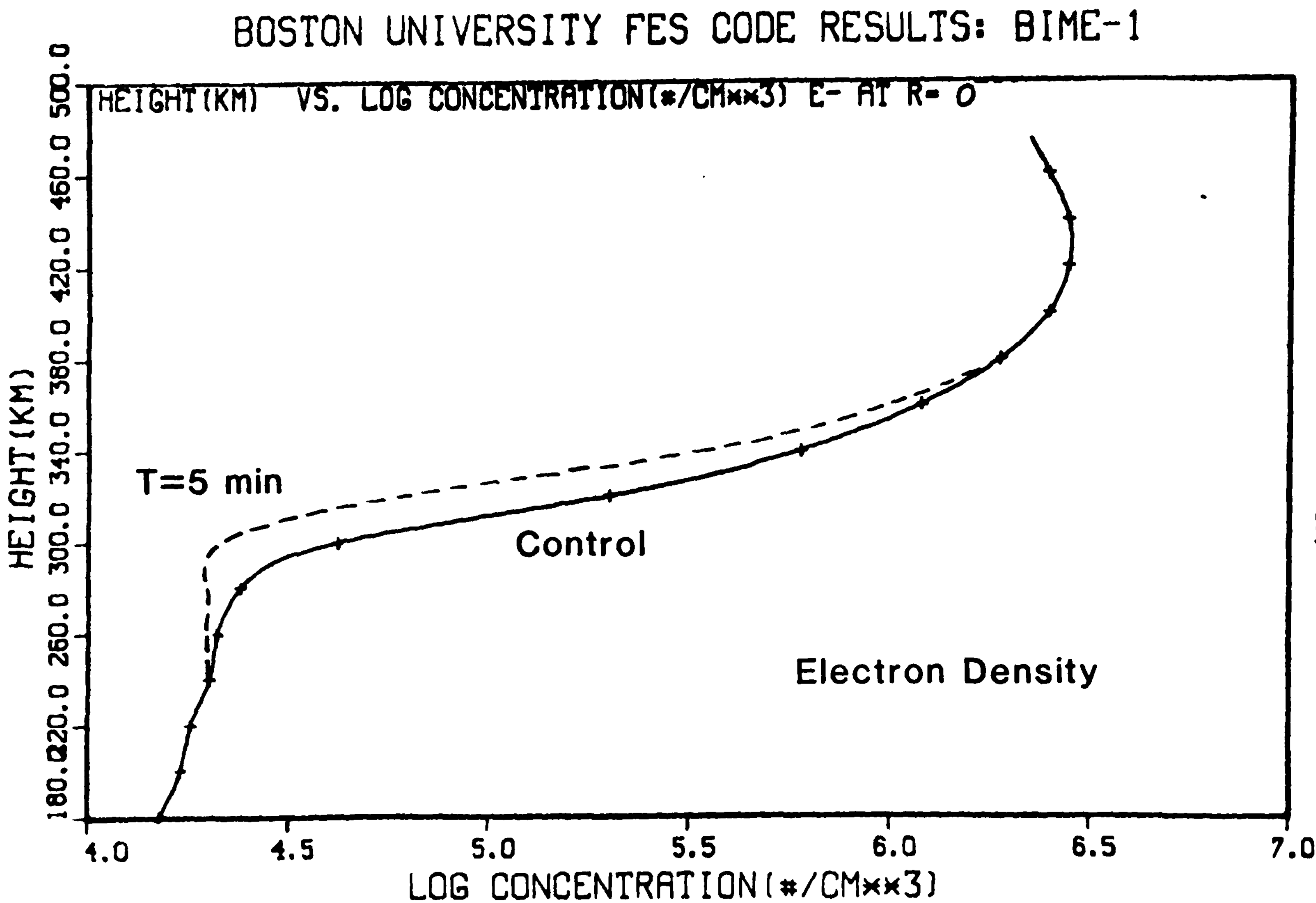


Figure 15. Electron Profile at T=5 min,R=0

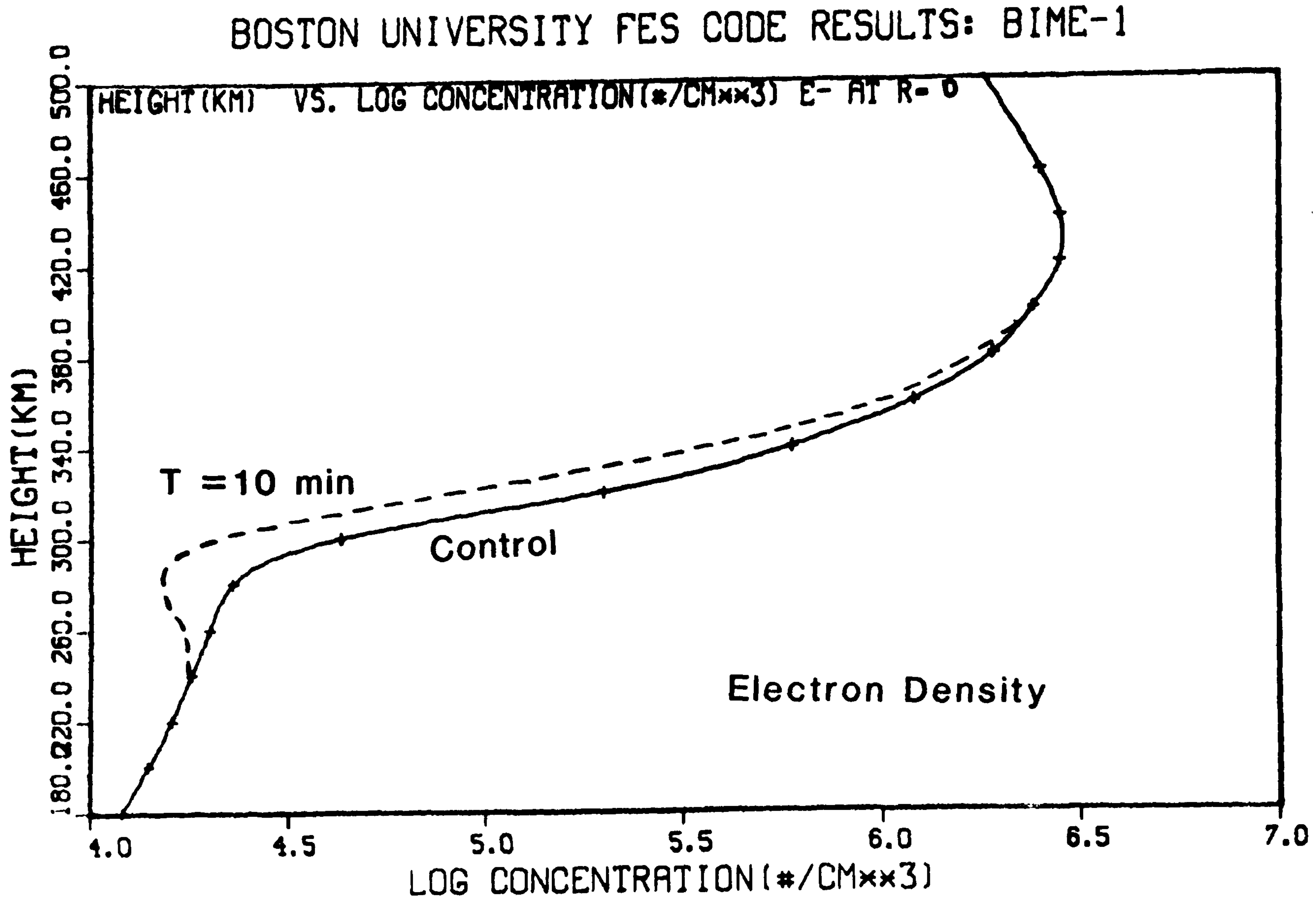


Figure 16. Electron Profile at T=10 min,R=0

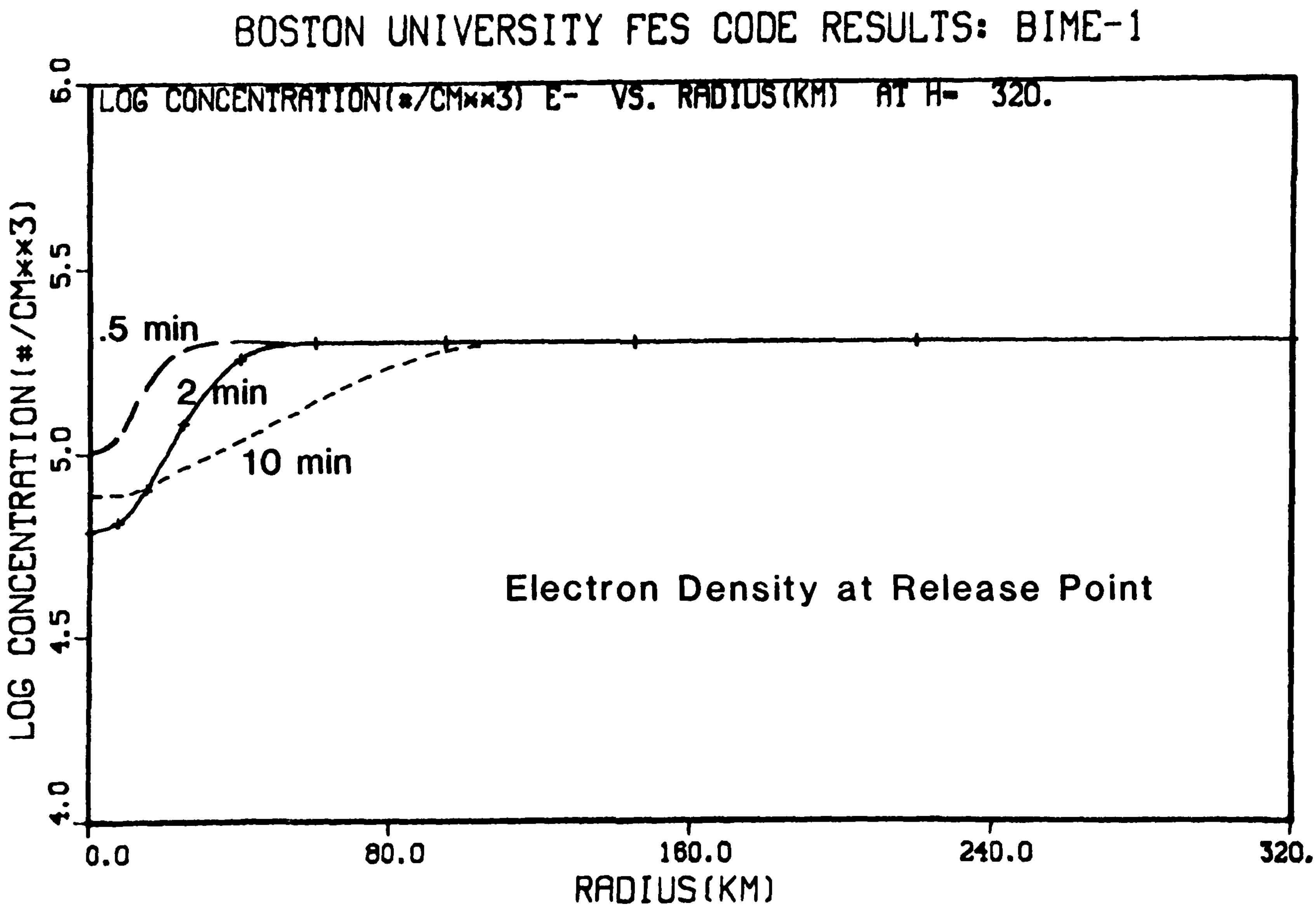


Figure 17. Electron Density vs. R at H=320 Km.

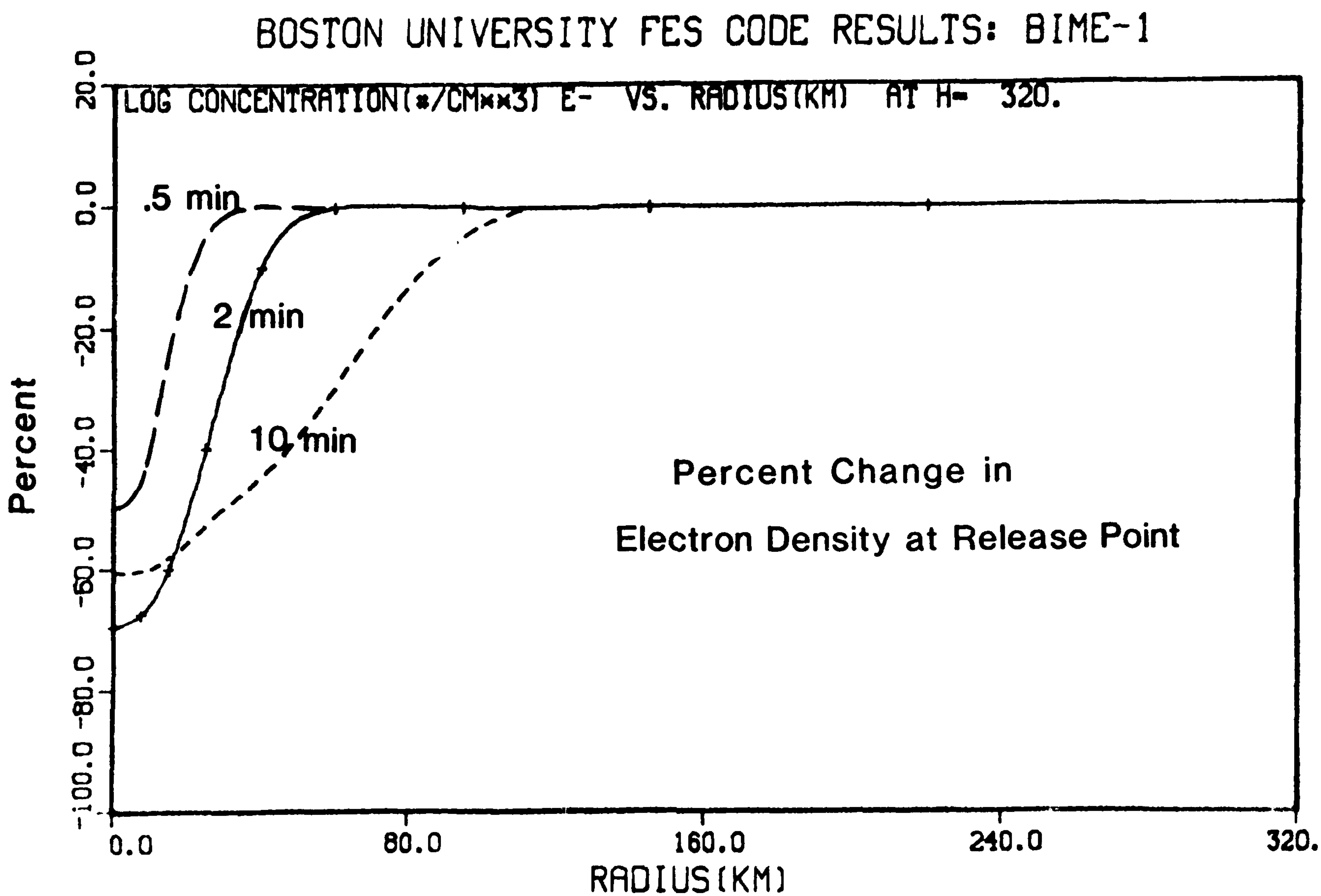


Figure 18. Percent Change in Electron Density vs. Radius

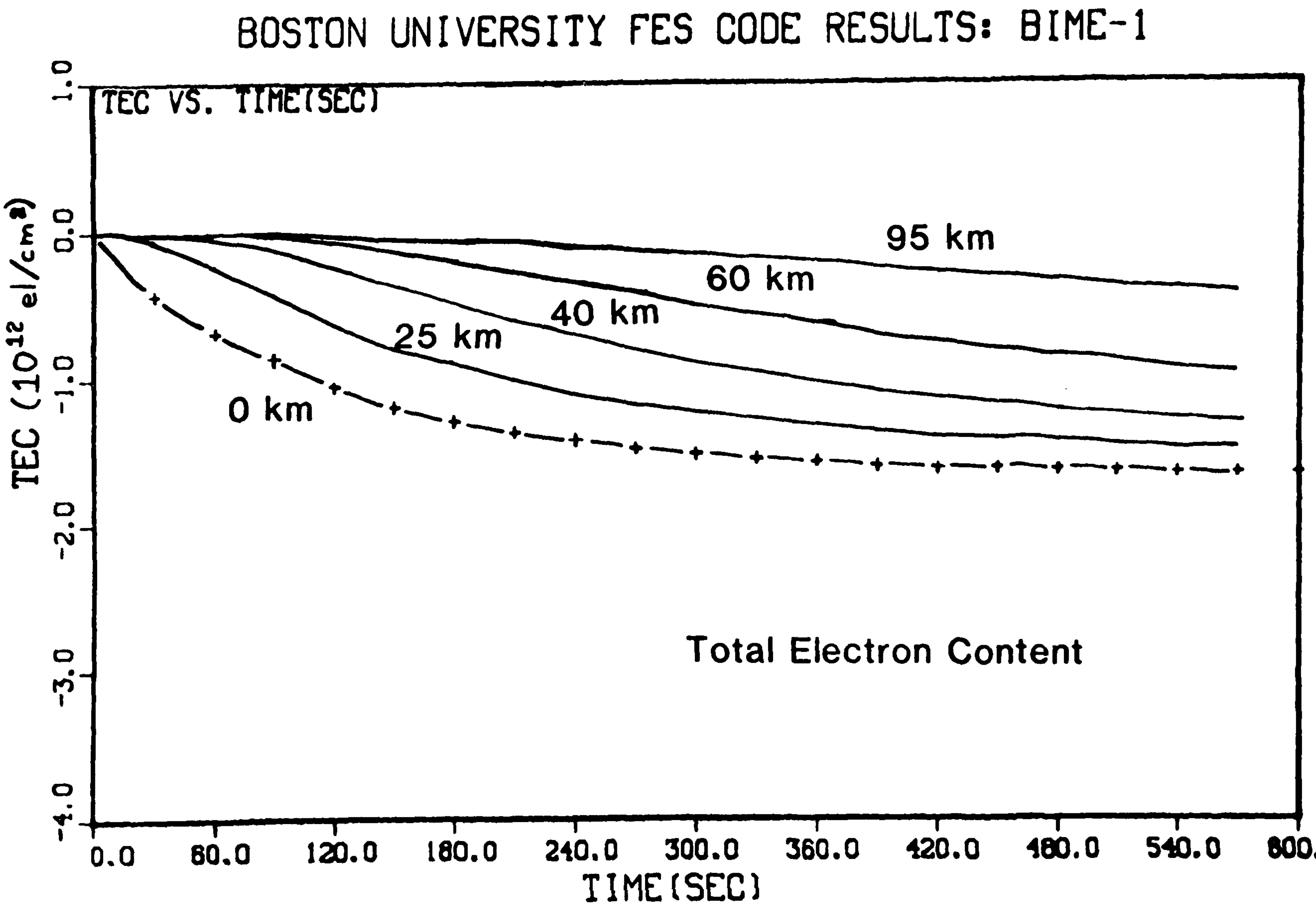


Figure 19. TEC vs. Time

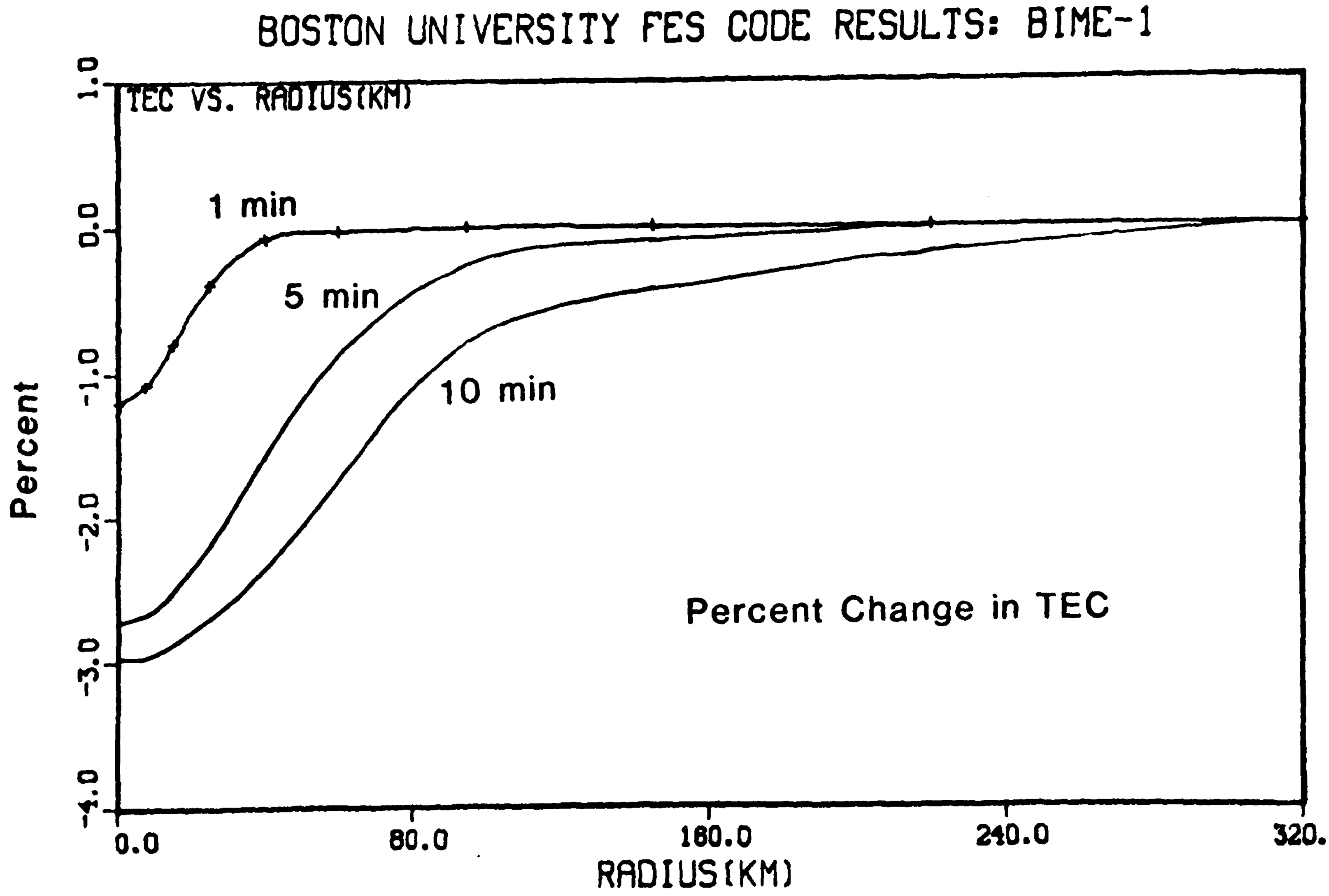


Figure 20. Percent Change in TEC vs. Radius

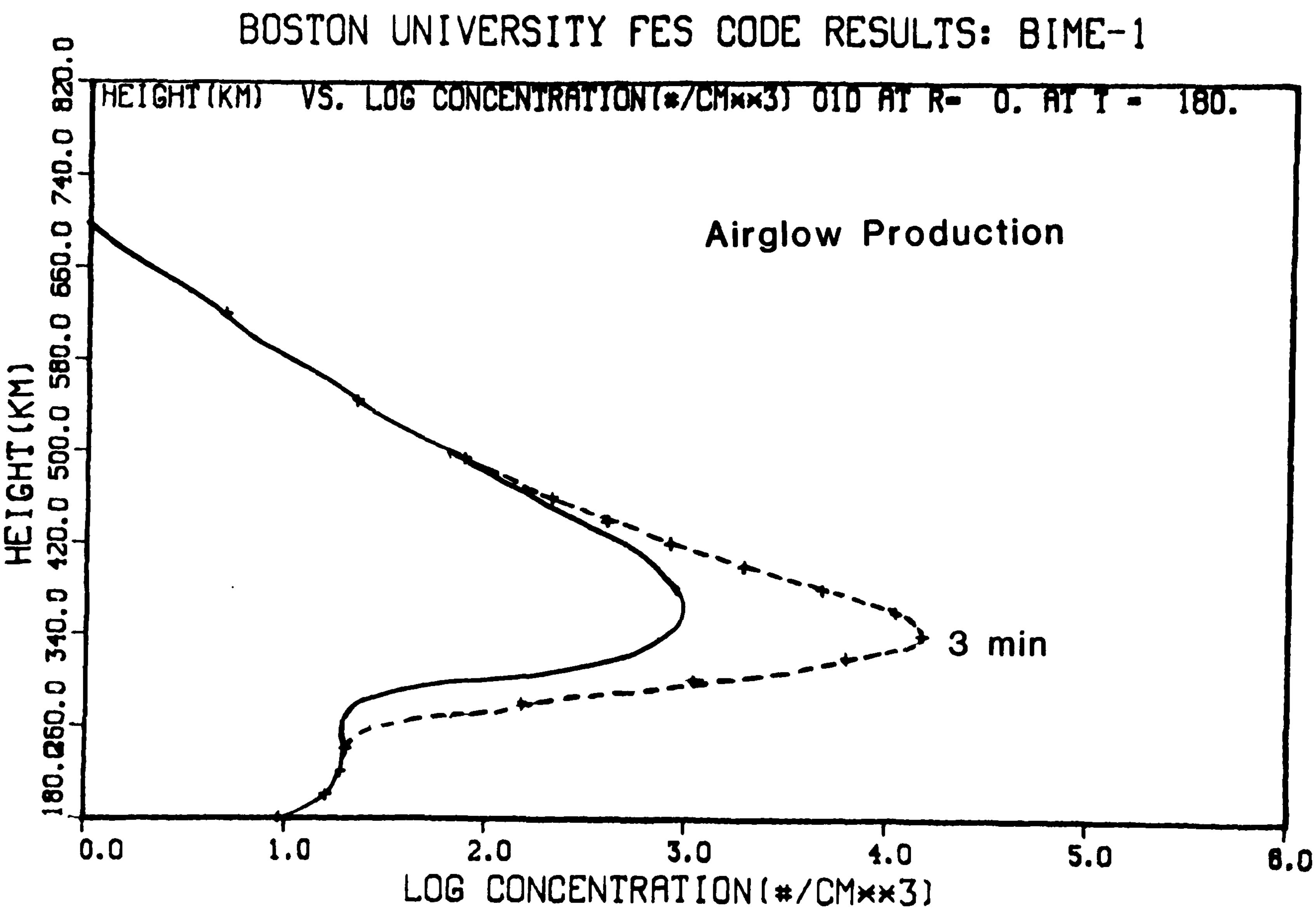


Figure 21. $O(^1D)$ Concentration vs. H

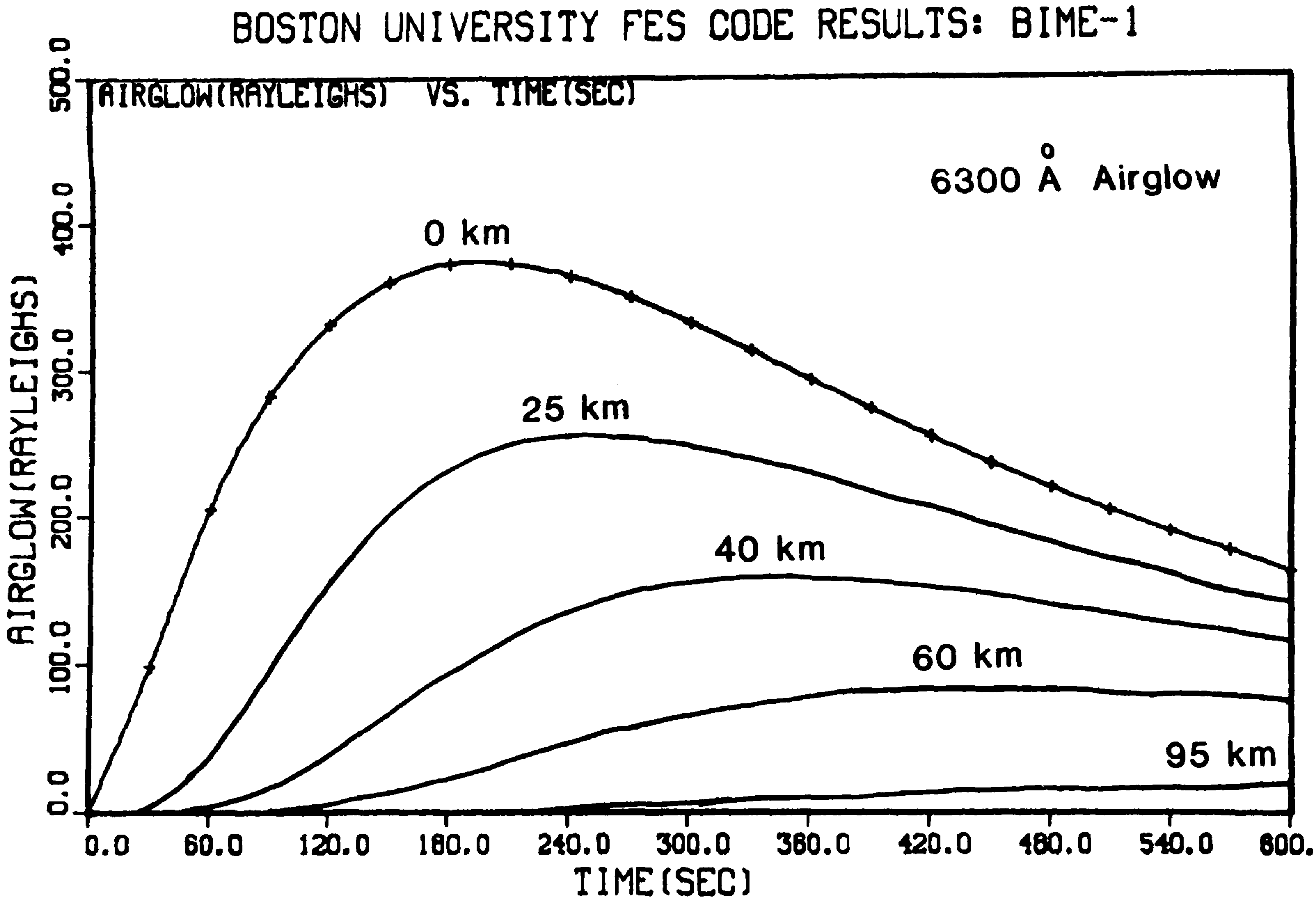


Figure 22. 6300 Airglow vs. Time

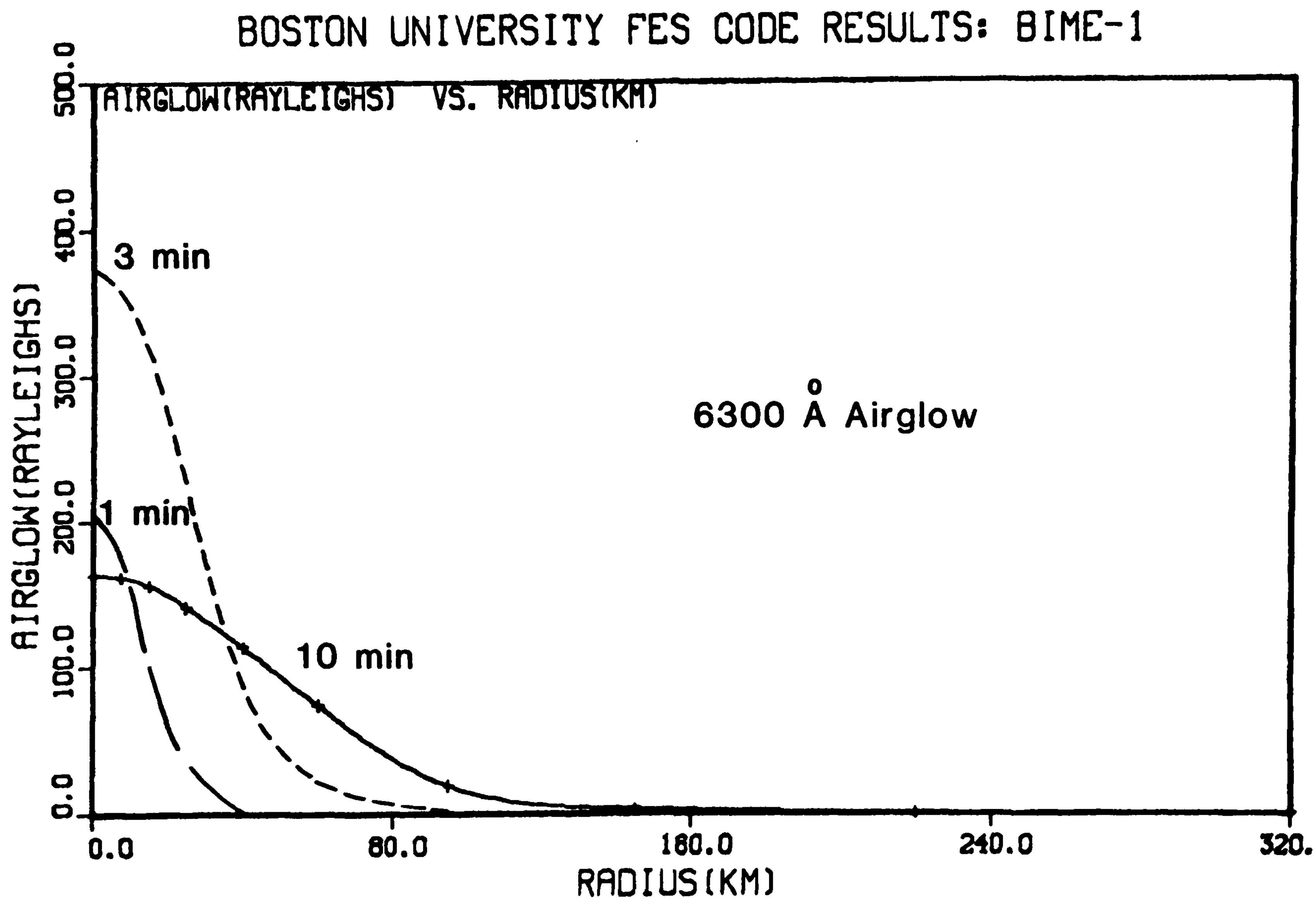


Figure 23. 6300 Airglow vs.

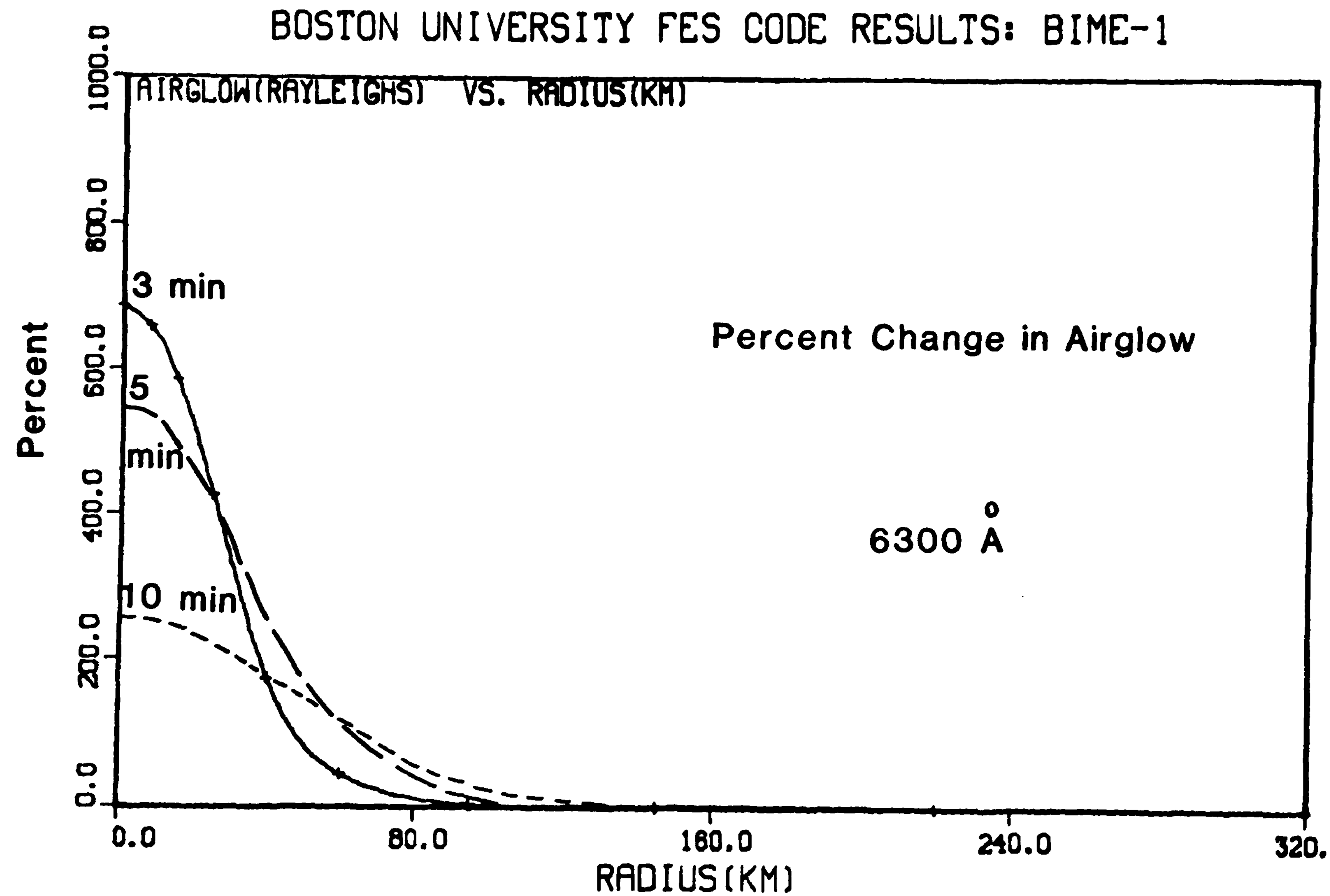


Figure 24. Percent Change in Airglow Vs. Radius

cent change in TEC was $\sim$1% the percent change in airglow is $\sim$50%.

A more detailed reduction of the BIME-1 airglow images and a refined set of simulation runs are currently in progress.

Reference

Vance, B., and Mendillo, M., Computer Simulation Techniques for Artificial Modification of the Ionosphere, AFGL-TR-81-0119, Air Force Geophysics Laboratory, Hanscom AFB, MA, April 1981. ADA102302

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